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METHODS OF TEST TO DETERMINE FLEXIBLE PAVEMENT REHABILITATION REQUIREMENTS BY PAVEMENT DEFLECTION MEASUREMENTS

CAUTION: Prior to handling test materials, performing equipment setups, and/or conducting this method, testers are required to read "**SAFETY AND HEALTH**" in Section G of this method. It is the responsibility of the user of this method to consult and use appropriate safety and health practices and determine the applicability of regulatory limitations before any testing is performed.

A. SCOPE

Five pavement deflection-measuring devices are described in this test method. Basically, the method consists of measuring the total deflection resulting from a load applied on the surface of the pavement.

B. EQUIPMENT

The five deflection measuring devices consist of a probe or sensor that measures pavement movements when subjected to some loading.

1. *Benkelman Beam.* This instrument (Figure 1) operates on a simple lever arm principle. It consists of a lower beam 3.66 m long that pivots at its third-point from an upper reference beam, which rests on the pavement behind the area of influence of the deflection basin. The front 2.44 m of the lower beam acts as a probe that moves vertically when the pavement deflects as the moving wheel load passes. The back 1.22 m then depresses a dial indicator that measures half of the maximum deflection to within 0.025 mm. The vehicle used for loading the measurement site should be a 44 kN truck that carries an 80 kN single axle test load (Figure 2). The tires shall be dual 279 mm x 572 mm in size, contain 12 plies, and are inflated to 483 kPa. The probe is inserted between one pair of dual tires so that its tip touches the pavement 1.37 m ahead of the center of the loading axle. (Trucks may have a dual tire spacing that is different from the spacing used on the *California Deflectometer*. Prior to use on test sections, run a correlation between the truck being used and the *California Deflectometer*.) The truck then slowly creeps forward. As the dual tires depress the pavement while passing by the probe tip, the lower beam rotates and changes the reading on the dial indicator.

2. *California Deflectometer.* This measuring device consists of a *Benkelman Beam* as defined above. The vehicle used for loading the measurement site is a towed semi-trailer that carries an 80 kN single axle test load. The distance from the kingpin to the rear axle is 8.10 m. The tires shall be dual 279 mm x 572 mm in size, contain 12 plies, and are inflated to 483 kPa. The rear dual wheels have been reconfigured and welded to provide 155 mm between the footprints of one pair. The probe is inserted between one pair of dual tires so that its tip touches the pavement 1.37 m ahead of the center of the loading axle. The truck then slowly creeps forward. As the dual tires depress the pavement while passing by the probe tip, the lower beam rotates and changes the reading on the dial indicator. [The *California Traveling Deflectometer* was a mobile, mechanized *Benkelman Beam* (Figure 3) with the tire size specified above. The rear dual wheels have been reconfigured and welded to allow room for the probe to operate between the dual tires. This device, built by Caltrans, was one of a kind and operated until about 1980. The trailer portion of the *California Traveling Deflectometer* was retained and is still

used with a *Benkelman Beam* as the California standard deflection-measuring device. This is now referred to as the *California Deflectometer*.]

3. *Dynaflect*. This small trailer (Figure 4) carries an electromechanical system for measuring the dynamic deflection of a roadway surface produced by an oscillatory load. It consists of a steady-state dynamic force generator made up of two flat-sided flywheels rotating at 8 hertz in opposite directions. This applies a force to the pavement of 4.45 kN, peak-to-peak, through two rubber-covered steel wheels. In operation, the Dynaflect must stop on the pavement and up to five sensors can be lowered to the surface for deflection readings. A portable unit is used to calibrate the system. Located in the tow vehicle is a control box used to operate the force generator, lower the sensors, and display the deflections.

4. *Road Rater (Model 400).* This device is commercially available in both vehicle and trailer mounted models. The models vary primarily in the magnitude of the load. The vehicle-mounted model 400, described herein, (Figure 5) operates at 25 hertz with a 3.79 MPa hydraulic system pressure and 1.47 mm mass displacement. While stationary the *Road Rater* applies a 2.67 kN peak-to-peak oscillatory load to the pavement surface through two steel pads. Two sensors measure the resulting pavement deflection. One is located at the center of loading and the other is 0.305 m away. Pavement deflections are displayed on the control box in the vehicle.

5. *Falling Weight Deflectometer*. This device (Figure 6) is commercially available in both vehicle and trailer mounted models. The models vary primarily in the magnitude of the load. All models operate on an impulse loading principle while stationary. A falling weight provides a force that can be varied depending on the height of fall and weight used. The energy is transferred to the pavement with a load pulse in approximately a half-sine wave form with 25 to 30 milliseconds duration through a plate that can vary in load contact area on most models. The motion induced in the pavement is measured by several sensors placed at the center of load and up to about 1.83 m away. The pavement surface deflection is displayed on a computer located in the tow vehicle. For this test method, the falling weight provides a 40 kN peak force and the energy is transferred through a plate 300 mm in diameter.

C. BACKGROUND DATA AND SELECTION OF TEST SITES

1. Preliminary Office Work:

   a. View computerized PhotoLog files and Pavement Condition Survey files to determine type of alignment; nature of distress and their locations; and unusual drainage conditions. If these files are not available, the project should be visually inspected to obtain these data prior to the deflection tests being performed.

   b. Determine the existing structural section from contract records; previous deflection studies; or obtain it from the district. Note all variations. If no structural section data are available, schedule cores to be taken.

   c. Obtain the design Traffic Index from the district.

   d. Arrange for maintenance personnel to perform traffic control.

2. Preliminary Field Work:

   Upon viewing the project in the field, it could be determined that some of the following may be done in conjunction with the data collection.

   a. Determine and record the nature, extent, and limits of the various distresses, such as rutting, bleeding, raveling, patching, potholes, and any localized failures. Also record the crack widths as hairline, 3 mm wide, 6 mm wide, or greater than 12 mm wide for longitudinal, transverse, alligator, and block cracking. Record the crack frequency as isolated, occasional, intermittent, nearly continuous, or continuous. Note the limits of structural section changes that are visible as well as local drainage problems, along with any vertical controls such as curbs, gutters, structures, and numerous roadway intersections. Record the lane widths.

   b. Generally, select a 300-m test section that represents each lane kilometer of roadway or, select a test section for each change in visual condition or known change in structural section if more frequent than one kilometer. Stagger the test sections in each lane to obtain good coverage of the pavement. If a project is less than 1.6 km in length, the entire project is considered the test section. If the route is multi-lane, the frequency may be reduced on the inner lanes to only one test section for each 8 km, unless visual conditions or structural section changes dictate more.

c. Reference each test section to a known or easily identifiable point in the field as well as the kilometer post limits.

d. Test sections must include sufficient sight distance in both directions in order to be safe. Therefore, if possible, the location of test sections on horizontal or vertical curves should be avoided.

e. Obtain representative photographs of each test section and all localized areas of major distress. Identify the project, location, and date on the photographs.

D. FIVE METHODS OF DATA COLLECTION

1. *Benkelman Beam* - WASHTO Method.

a. Bring test vehicle to a stopped position at the beginning of the test section with the dual tires on the wheel track to be tested.

b. Position the beam between the dual tires so that the probe is 1.37 m forward of and perpendicular to the rear axle.

c. Activate the vibrator and adjust the dial indicator to read zero.

d. Drive the test vehicle approximately 8 m forward at creep speed and record the maximum dial reading (D_i) to the nearest 0.025 mm.

e. After the test vehicle has past and the dial needle has stabilized, record the final dial reading (D_f) to the nearest 0.025 mm.

f. Repeat this process at approximately 8-m intervals longitudinally along centerline, alternating between wheel tracks, obtaining two measurements in the outer wheel track for every one measurement in the inner wheel track throughout the test section.

g. Record the location and *Benkelman Beam* pavement deflections on appropriate data sheet.

Pavement deflection = 2 (D_i) - D_f

2. *California Deflectometer.*

a. Bring test vehicle to a stopped position at the beginning of the test section with the dual tires on the wheel track to be tested.

b. Position the beam between the dual tires so that the probe is 1.37 m forward of and perpendicular to the rear axle. (See Figure 5)

c. Activate the vibrator and adjust the dial indicator to read zero.

d. Drive the test vehicle approximately 15 m forward at creep speed and record the maximum dial reading (D_i) to the nearest 0.025 mm.

e. After the test vehicle has past and the dial needle has stabilized, record the final dial reading (D_f) to the nearest 0.025 mm.

f. Repeat this process at approximately 15-m intervals longitudinally along centerline, on the wheel track which exhibits the most distress, generally the outside wheel track. Obtain twenty-one deflection measurements for the test section, if possible.

g. Record the location and *California Deflectometer* pavement deflections on appropriate data sheet.

Pavement deflection = 2 (D_i) - D_f

3. *Dynaflect.*

a. Prepare the unit for deflection testing.

b. Calibrate the unit at the beginning of the shift. When the air temperature change during the work shift is about 5°C recalibrate the unit.

c. Bring test vehicle to a stopped position at the beginning of the test section and take a measurement with the trailer centered on the wheel track which exhibits the most distress, generally the outside wheel track. The single No. 1 sensor (maximum deflection reading) is sufficient for most work.

d. Drive the tow vehicle forward approximately 15 m after each measurement. Obtain twenty-one deflection measurements for the test section, if possible.

e. Record the location and pavement deflections on appropriate data sheet.

f. Each *Dynaflect* reading must first be converted to an equivalent deflectometer reading before the mean and 80th percentile deflections are calculated. The correlation curve for each *Dynaflect* verses *California Deflectometer* has been determined, through experience, to be non-linear and unique.

4. *Road Rater – Model 400.*

a. Prepare the unit for deflection testing.

b. Calibrate the unit at the beginning of the shift.

c. Bring test vehicle to a stopped position at the beginning of the test section, centered on the wheel track which exhibits the most distress, generally the outside wheel track, and take a measurement. The No. 1 sensor, at center of loading, is sufficient for most work.

d. Drive the test vehicle forward approximately 15 m after each measurement. Obtain twenty-one deflection measurements for the test section, if possible.

e. Record the location and pavement deflections on appropriate data sheet.

5. *Falling Weight Deflectometer*.

a. Prepare the unit for deflection testing.

b. Exercise the unit at the beginning of the shift.

c. Bring test vehicle to a stopped position at the beginning of the test section, centered on the wheel track which exhibits the most distress, generally the outside wheel track, and take a measurement. Apply the loads using the following sequence:

(1) One seating drop to ensure proper contact.

(2) Three drops with an applied load of 40 kN $\pm$ 10 %.

Deflections are recorded from all sensors for each drop except the seating drop. For this method the average deflection from the three 40 kN drops is used for calculations.

d. Drive the tow vehicle forward approximately 15 m after each measurement. Obtain twenty-one deflection measurements for the test section, if possible.

e. Save the location and pavement deflections on the computer disk or record on appropriate data sheet.

E. DOCUMENTATION AND CALCULATION

1. Record all observed pavement conditions; road intersections; locations of large cuts and fills; vertical control features; kilometer post markers; and air and pavement surface temperatures. Also record any localized drainage and/or embankment settlement problems; and any core and existing structural section data removed from the wheel track in which the deflections are measured.

2. Convert to Equivalent Deflectometer Values.

a. For the *Benkelman Beam, California Deflectometer, Road Rater*, and *Falling Weight Deflectometer* calculate the mean (average), and the 80th percentile deflection level (where 20 % of the deflections are higher and 80 % are lower than this level) from the measurements of the test section.

$$\bar{X} = \sum D/n \qquad \& \qquad D_{80} = \bar{X} + 0.84s$$

where:

$\bar{X}$ = mean deflection
D = recorded deflection
D_{80} = 80th percentile deflection
n = number of test points per test section
s = standard deviation of all test points per test section

Then for the *Benkelman Beam*, *Road Rater,* and the *Falling Weight Deflectometer* convert the mean and 80th percentile to equivalent deflectometer values using the appropriate correlation curve established by each user. The *California Deflectometer* mean and 80th percentiles are used as calculated and are not converted.

b. For the *Dynaflect*, convert the individual measurements to equivalent deflectometer values using the appropriate conversion chart for the Dynaflect used. Again, each user should establish their own correlation. Using these values calculate the equivalent deflectometer values for the mean and 80th percentile.

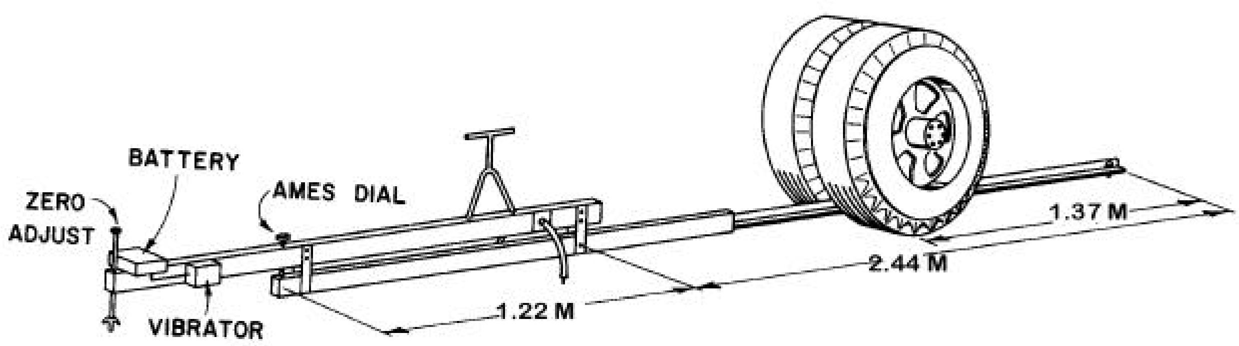
c. A comparison of each deflection-measuring device to the *California Deflectometer* should be performed at least once a year. The results should be recorded in an appropriate form that is easy to use.

F. HAZARDS

Prior to handling, testing or disposing of any waste materials, Caltrans testers are required to read: Part A (Section 5.0), Part B (Sections 5.0, 6.0, and 10.0), and Part C (Section 1.0) of the Caltrans Laboratory Safety Manual. Users of this method do so that their own risk.

Refer to Chapter 8 of the Caltrans Maintenance Manual for proper traffic control.

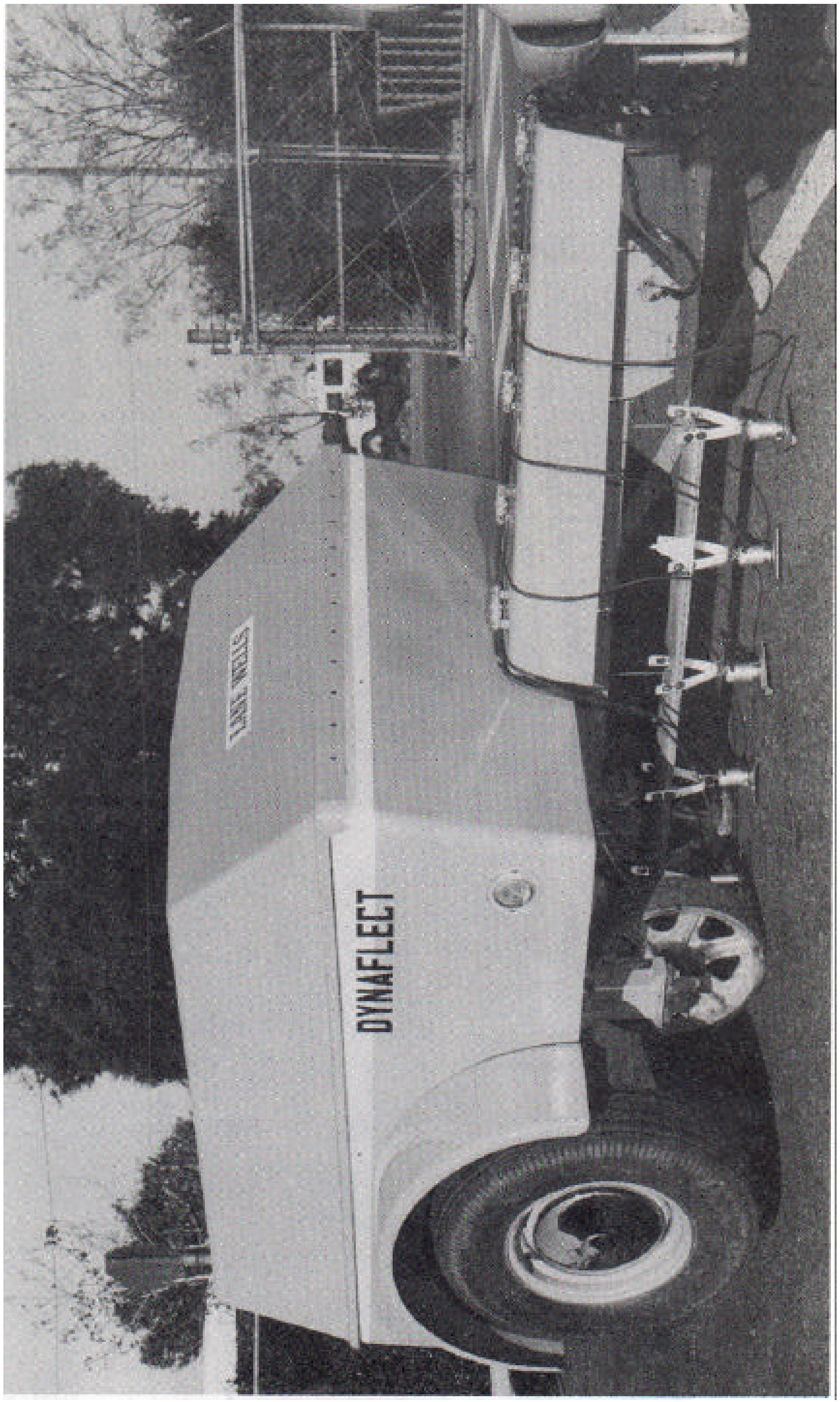
End of Text (California Test 130 contains 10 pages)



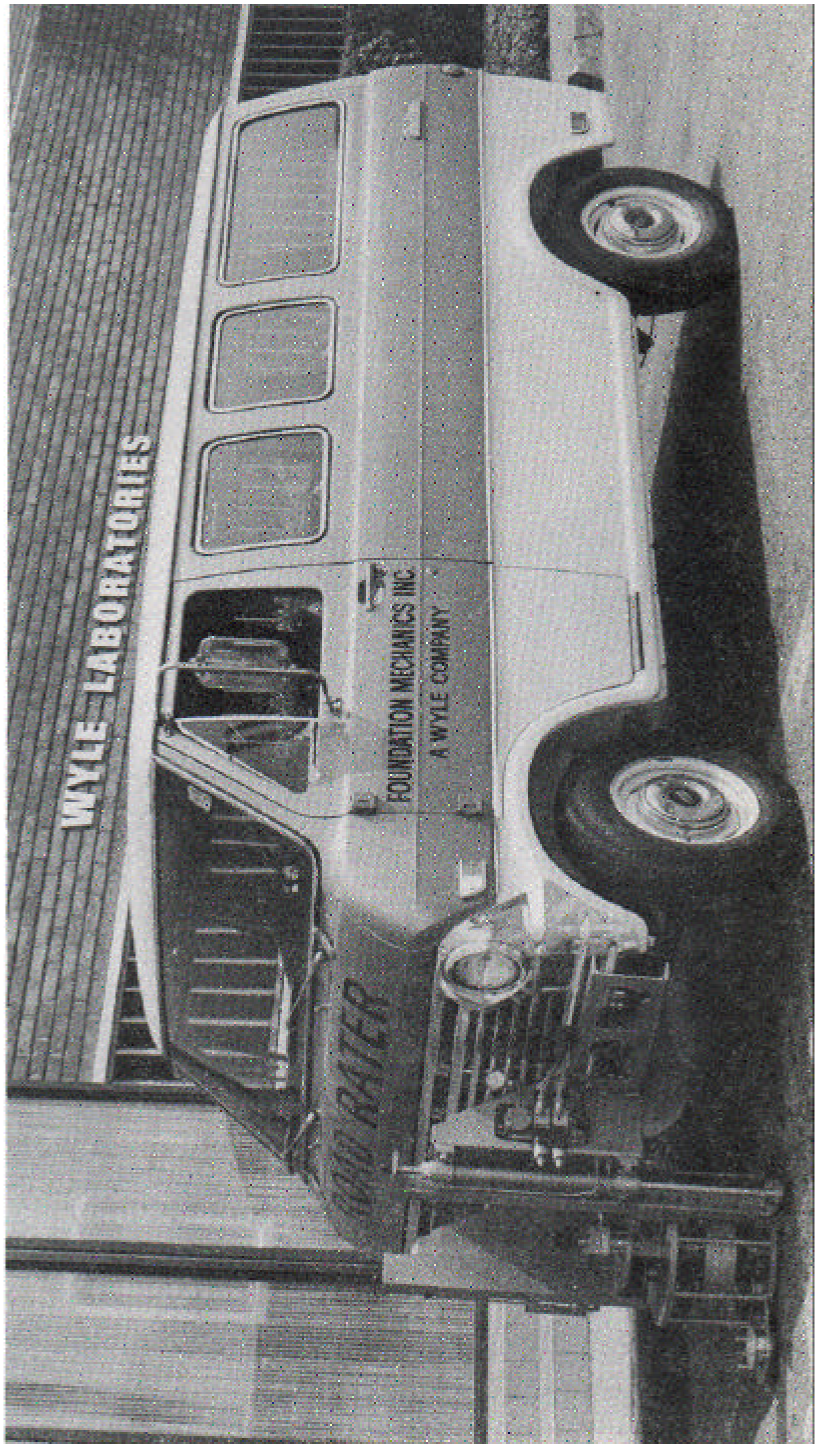
Benkelman Beam
FIGURE 1

FIGURE 2

California Traveling Deflectometer
FIGURE 3



Dynaflect
FIGURE 4



Road Rater (Model 400)
FIGURE 5

Falling Weight Deflectometer
FIGURE 6